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CIRCUIT PROTECTION USING THERMAL IMAGING AND ITS PROCESSING TECHNIQUES

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Abstract: *Protection is always an essential parameter of an electrical circuit system. As per electrical fundamental rules, short circuit occurs due to high current passes through an electrical connection. This high called an overcurrent may burnout further circuitry or may blast an important and expensive instruments connected to it. So, it is always mandatory to solve this problem by detecting overcurrent before any harmful incident. Actually, an overcurrent passing through any wire or any component will increase temperature of surrounding areas. If we can detect that high temperature then it is possible to protect the whole circuits and also connected instruments further by removing its supply. To do the same, images acquired from thermal imaging camera can be used to detect temperature of an area and also it helps to solve this problem without coming into the contact. In this paper, I have tried to protect electrical circuit using different but simple image processing techniques using machine vision system. I have used electrical circuit images acquired from thermal imaging camera. By means of different image processing techniques, I have found overheated area in an image due to overcurrent flows in a circuit. After successful detection and analysis of an overheated area, one can easily save and protect the circuit by making off the partial or whole supply to the circuit.*

Keywords: *Infrared Thermal imaging, Thresholding, Image processing technique, Electrical circuit protection, overheated.*

1. INTRODUCTION

For any human being, it is difficult to measure high temperature of surrounding area near any live electrical connection or temperature of surrounding area of a running motor or actuator without coming into contact. Hence it is also difficult to continuously track the temperature of this type of system. Now, in this type of system, if any problem exists at certain time then it is yet difficult but needed to take quick action to overcome any damage. In [1] Jibu Vargese et al. used thermal image analysis technique to find out loading condition of PCB based on thermal camera image. In [2] TANG Qingju et al., compared and analyzed

ant colony algorithm and canny operator to extract required parameter from infrared thermal images. In [3] TANG Qingju et al., discussed about fusion of morphology and canny algorithm in Infrared image edge detection. In [4] Aleksandra Pavlović et al. discussed about fusion of visual and thermal image to find area of interest from thermal images. In [5] S. Harishkumar et al., has worked on hot spot occurs due to transformer heating. So, Inspired from the above papers published based on thermal camera in this paper, I have tried to track temperature continuously using thermal camera. I have used two images having area of normal temperature and high temperature. I have drawn out area of interest using image processing technique discussed below.

2. PROBLEM DEFINITION

An Industry comprises of many expensive instruments, products etc. In today's era, anything related to an industry or house hold instruments or products has to deal with electrical parameters such as current, voltage, power etc. The current passing through an instrument plays major role in electrical parameters and it should be within limited range. If it is more than a maximum limited range then this may create unexpected damage to the product or major blast in an industry. To save the instrument or to protect an industry from an unexpected electrical damage, one has to sense the overcurrent problem flows through the circuit. It is possible to sense overcurrent and cutoff further circuitry of an instrument. In this paper, not only over current but, I have also tried to find exact wire or connection from which overcurrent or beyond limit current is flowing. The current passing through the circuit of an instrument will increase the power consumed by the wire and ultimately the instrument. The more power consumed by the wire will increase surrounding temperature which is quite differ from ambient temperature.

It is not possible to find overheated area of circuit from an image taken by normal camera as shown in Figure 1. But temperature difference can be sensed or detected in an image taken by thermal imaging camera as shown in Figure 2. It can be easily seen that one of the wire shown in Figure 2 carries more current as compare to others. By using an image from thermal imaging camera, I have used remote sensing type technique to sense the temperature rise due to overcurrent flow. After certain image processing steps followed described as under, a user can easily detect overcurrent flow. To resolve it, user can either

switch off the supply or do necessary action to limit the temperature or current within defined range.

Figure 1: Image taken by Normal Camera

Figure 2: Image taken by Infrared Thermal Imaging Camera

(source:http://www.cheyenneelectric.com/thermographic-scanning-service)

3. IMAGE PROCESSING TECHNIQUES AND OTHER METHOD USED

I have used below mention image processing related techniques to solve the sudden rise in surrounding temperature of an electrical circuitry.

3.1 Infrared Thermal Imaging

Thermal imaging is a method of improving visibility of objects in a dark environment by detecting the objects' infrared radiation and creating an image based on that information. Night vision technologies that are most commonly used are near-infrared illumination, low-light imaging and thermal imaging. Thermal imaging works in environments without any ambient light. Fog, haze and smoke can be penetrated by thermal imaging just like near-infrared illumination [1].

All objects emit infrared energy as a function of their temperature. Heat signature is the infrared energy produced by an object. More radiation is been emitted as the object becomes hotter. Tiny differences in temperature can be detected using a heat sensor called as thermal camera. Infrared radiation is collected by the device from objects in the scene and creates an electronic image based on temperature differences information. Thermal camera can detect each object distinctly and can give a distinctive image as the objects that are closer very rarely have precisely same temperature. Grayscale images are obtained using a thermal camera. Cold and hot objects look black and white respectively whereas variation between two is indicated by depth of gray. Different temperatures are indicated

by different colors in some thermal cameras [1]. Different temperature colors can be seen in Figure 3.

3.2 Channels in color image

In RGB color model, each colour appears in its primary spectral components of red, green and blue. The colour of a pixel is made up of three components; red, green, and blue (RGB), described by their corresponding intensities. Colour components are also known as colour channels or colour planes (components). In the RGB colour model, a colour image can be represented by the intensity function [8]I_{RGB}.

$$I_{RGB} = (F_R, F_{G,} F_B) \qquad (1)$$

Where $F_R(x,y)$ is the intensity of the pixel (x,y) in the red channel, $F_G(x,y)$ is the intensity of pixel (x,y) in the green channel, and $F_B(x,y)$ is the intensity of pixel (x,y) in the blue channel. The intensity of each colour channel is usually stored using eight bits, which indicates that the quantization level is 256 [6]. I have extracted red channel image from an infrared thermal image.

3.3 Threshold selection [7]

Thresholding is the simplest method of image segmentation. From a grayscale image, thresholding can be used to create binary images.

The key parameter in the thresholding process is the choice of the threshold value. Several different methods for choosing a threshold exist; users can manually choose a threshold value, or a thresholding algorithm can compute a value automatically, which is known as automatic thresholding.

In a noiseless image with uniform background and object values, the mean or median will work well as the threshold, however, this will generally not be the case. A more sophisticated approach might be to create a histogram of the image pixel intensities and use the valley point as the threshold. The histogram approach assumes that there is some average value for the background and object pixels, but that the actual pixel values have some variation around these average values [7].

Global (single) thresholding method is also used when there the intensity distribution between the objects of foreground and background are very distinct. When the differences between foreground and background objects are very distinct, a single value of threshold can simply be used to differentiate both objects apart. Thus, in this type of thresholding, the value of threshold depends solely on the property of the pixel and the grey level value of the

image. Some most common used global thresholding methods are Otsu method, entropy based thresholding, etc [8].

Thresholding is the simplest segmentation method [9].The pixels are partitioned depending on their intensity value. I have used Global thresholding, using an appropriate threshold T given by below equation.

$$g(x,y) = \begin{cases} 1, & if\ f(x,y) > T \\ 0, & if\ f(x,y) \leq T \end{cases} \qquad (2)$$

3.4 Region of interest

A region of interest (ROI) is a portion of an image that has to be processed and analyzed. An ROI is defined by masks. The concept of an ROI is used in many application areas such as, in medical imaging, thermal imaging etc., to find the boundaries of an object. Region of interest can be selected manually or automatically [10]. This method is not mandatory in our case but user may use this to get better result.

3.5 Temperature color graph

The temperature color graph is shown in Figure 3 below for certain infrared thermal imaging sensor. By seeing this graph, one can easily find the temperature of corresponding color in an image as per Figure 3. This figure is shown as per reference. The temperature varies according to infrared thermal imaging sensors. In that graph the range of red color shows high temperature regions. So whenever infrared thermal imaging sensor senses red color, it means that area has got very high temperature can be called overheated area and else will be considered as normally heated area. I have concentrated on red color and beyond that to find out overheat area in an image.

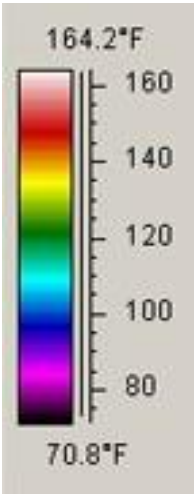

Figure3. Temperature color Graph

4. ALGORITHM/METHOD USED

Table-I will define the steps or methods to resolve the problem discussed above.

Table-I

Steps	Method used
1	Acquire an Image of an electrical circuit from thermal imaging camera as shown in Figure 2.
2	Cropped Figure 2 and extract two different images defined overheated image area as shown in Figure 4 and normally heated image area as shown in Figure 5.
3	Extract red channel images of both overheated and normally heated images as shown in Figure 6 and Figure 7 using color separation technique.
4	Apply global thresholding to both Red channel Images with well-defined threshold level as shown in Figure 8 and Figure 9.
5	The user can also skip step 2 to step 4 by selecting region of interest in thermal image shown in Figure 2 to find overheated area and normally heated area.
6	After thresholding, an image will be divided in binary levels or black and white levels as shown in Figure 8 and Figure 9.
7	Once binary images are extracted, then it is possible to find area filled by two different colors such as black and white in terms of pixels as shown in Table II by using function of region props in MATLAB.
8	Normalization and simple arithmetic conversion method helps to find the areas extracted in terms of pixels into the form of percentage of images shown in Figure 8 and Figure 9.
9	After Having final maximum limit area covered for overheated temperature in an image, user can easily decide whether temp is normal or overheated. In our case above 40% area covered by white region is known as overheated.

Figure 4. Overheated area of an image

Figure 5. Normal heated area of an image

Figure 6. Red Channel image of an Overheated image area

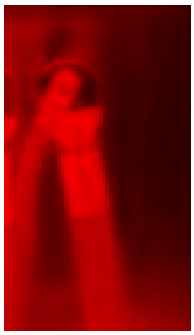

Figure 7. Red Channel image of an normally heated image area

Figure 8. Thresholded image of an Overheated image area

Figure 9. Thresholded image of normally heated image area

Table-II

Sr. No.	Areas found							Decision
	Total Area	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	
1	1840.8 (In Pixel)	8	25	2	2	1	1	Normal heat (Low Temp)
	100 (In %)	0.4388	1.3713	0.1097	0.1097	0.0549	0.0549	
2	1840.8 (In Pixel)	**915**	1	26	---	---	---	Overheat (High Temp.)
	100 (In %)	**49.706**	0.0543	1.4124	---	---	---	

5. RESULT

After applying certain image processing and thresholding technique, I have found images shown in Figure 8 and Figure 9having two different areas filled with black and white color. In those images white area describes temperature rise in that area and black means normal or below maximum limit temperature is maintained. Region finding technique will provide you information regarding filled area in terms of pixels as shown in Table II. Filled area in

terms of percentage as shown in Table-II will be found by using normalization and simple arithmetic conversion method.

6. CONCLUSION

One should be aware about relation of current and temperature rise in particular wire or component to protect circuitry. Whenever current rises it will increase the temperature in that particular surrounding area. So, to differentiate between normal temperature area and overheated area user should observe thresholded image as shown in figure. First, the user must decide about certain limit of maximum level of area affected from high temperature. So I am finding the area in terms of percentage which is overheated due to temperature and ultimately due to overcurrent drawn from circuit. After seeing Table-II, one can easily decide about normal temperature area and overheated area shown in terms of pixel and in percentage as well. Now, user can easily find area from which overcurrent is drawn in circuit and take necessary action to resolve it.

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